STUDIES IN AUSTRALIAN *NEUROPTERA*.

No.7. The Life-History of *Psychopsis elegans* (Guérin).

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(Plate lxxix., and twelve Text-figures).

The only account of the life-history of any species of the family *Psychopsidæ* is the short, popular account of the life-history of *Psychopsis elegans* Guérin, given by Mr. Luke Gallard in the "Australian Naturalist" of 1914.* From this we learn that Mr. Gallard captured a female of *Ps. elegans* (he uses the synonym *newmani* Froggatt, throughout, for this species) at Kenthurst, N.S.W., in 1904. This insect laid over fifty eggs, some of which Mr. Gallard raised to about one-third of the full larval size. Mr. Gallard informs me that it was one of these specimens, newly hatched, which is figured on p.62 of Mr. Froggatt's "Australian Insects" as the larva of *Psychopsis mimica* Newman.

Mr. Gallard did not succeed in rearing the imago until 1911. A larva taken in March, 1911, by Mr. J. Blake, of Narara, near Gosford, N.S.W., was kept alive by Mr. Gallard until December 11th of the same year, when it spun a cocoon in the box, the imago emerging on January 16th, 1912. Since then, Mr. Gallard has discovered the larvæ in many localities round Sydney, and has bred a number of specimens.

In 1915, when I had begun the study of the Neuroptera Planipennia, and was very anxious to study the *Psychopsidæ* in particular, Mr. Gallard very generously invited me to accompany him in the field, and showed me the ingenious ways by which he found these larvæ. I shall never forget the skill and energy that he displayed in this work. As the whole credit for the discovery of this larva rests with him, and is simply due to his

* "Notes on *Psychopsis newmani*." By Luke Gallard, Australian Naturalist, iii., Part 3, 1914, pp.29-32.

persistence and keenness in following up clue after clue for many years, I should like to take this opportunity of congratulating him upon the fine results of his work, and of thanking him very heartily for the help offered to me, without which I feel quite certain that neither I nor anyone else could possibly have hit upon the track of such a remarkable larval form as this.

Since Mr. Gallard first taught me how to find this larva, I have discovered it in many localities around Sydney, also near Wauchope on the North Coast of N.S.W., and in many places in S. Queensland, including Brisbane (One-Tree Hill), Stradbroke Island, Mount Tambourine, Caboolture, Caloundra, and Landsborough. It probably occurs all along the Eastern Coastline of New South Wales and Queensland, wherever there are suitable rough-barked, Myrtaceous trees for the larva to hide in.

In the present paper, I propose to give a full description of the egg, larva, and pupa, together with an account of the habits of the larva, the spinning of the cocoon, the emergence of the imago, and some details about the latter that have not yet been carefully investigated.

My thanks are due to my wife for the execution of Plate lxxix., from the living larva and pupa, in collaboration with myself.

The Life-cycle of Psychopsis elegans (Guérin).

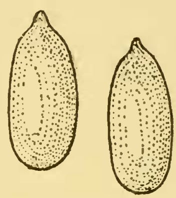
The complete life-cycle of this species occupies about two years. The larva, like almost all others of this Order, has only three instars, during each of which an enormous increase occurs in the size of the body, the size of the head remaining constant in the meanwhile. The following Table exhibits the duration of each period :—

Period.	Duration.
Egg	About twelve days.
First larval instar ..	About eight months, including hibernation. (Feb.-Sept.).
Second larval instar ...	From four to five months, without hibernation. (Sept.-Feb. or March).
Third larval instar ...	About nine months, including a second hibernation, and a fortnight to three weeks within the cocoon before pupation. (March-Nov.).
Pupa	About three weeks.
Imago	About two months. (Dec.-Feb.)

The Egg. (Plate lxxix., fig. 1; Text-fig. 1).

The eggs are laid separately, or only two or three together, at considerable intervals of time; probably, in the natural state, upon the bark of Myrtaceous trees, especially Eucalypts. In captivity, most of the eggs were laid upon cotton-wool. They are not stalked, and are laid upon one side, which is attached to some object by a slight secretion of gelatinous matter.

The egg itself is oval, about 1 mm. long by 0·45 mm. wide in the middle, and is of a semi-opaque creamy colour, tinged with pale green. At its anterior end there is a distinct micropylar projection, as shown in Text-fig. 1. The egg is quite smooth, without any pattern or sculpture.



Text-fig. 1.*

The eggs are usually laid in January or February. At the end of about twelve days, they hatch. The young larvæ, hitherto curled up inside, crawl straight out of the broken shell, and at once make for some small crack or crevice in the bark, where they may escape the numerous enemies that would otherwise speedily compass their destruction.

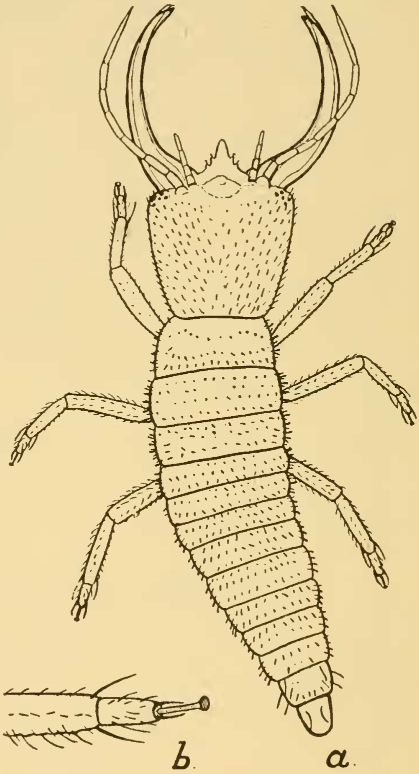
First Larval Instar. (Plate lxxix., figs. 2-3; Text-fig. 2).

The newly-hatched larva is somewhat more than three times as long as the egg in which it was confined, the measurement being taken from the tip of the mandible to the anal papilla. As with all Planipennia, such a comparatively large larva can only be contained within the egg by considerable folding of parts; the head being tucked down below the breast, and the posterior half of the abdomen being again folded forwards under the head.

At first, before the larva has taken any food, the head is very large in comparison with the rest of the body. But, after one or two large meals, the abdomen begins to be distended with food, and the general appearance of the larva undergoes a great alteration, as can be seen by comparing Plate lxxix., figs. 2 and 3. This change takes place in every instar of all Neuropterous larvæ

* Two eggs of *Psychopsis elegans* (Guér.); (×20).

known to me. The reasons for it are two; firstly, that there are only three or four larval instars in this Order; and, secondly, that no food at all is excreted, the waste-products being stored in a special sac or chamber of the alimentary canal, which is not cast out until the emergence of the imago. Hence it is clear that a large increase in the size of the abdomen is inevitable during each larval instar, whereas the size of the head can only be increased at ecdysis.



Text-fig. 2.*

The head of the young larva is somewhat flattened, trapezium-shaped, and wider in front than behind; length about 0·6 mm., breadth in front about the same. At the two anterior angles, which are somewhat rounded, are the two groups of simple eyes, occupying the area from which the compound eyes of the pupa and imago are later developed. There are five ocelli in each group. The anterior border of the head projects in the middle to form the prominent triangular *labrum*, on either side of which lie the long, slender *antennæ*, which are eight-jointed. The mouth-parts are very extraordinary, consisting of a pair of

* Newly-hatched larva of *Ps. elegans* (Guér.); (×30): *b*, part of hind leg of same, to show tarsal claws and empodium, the latter in the form of an elongated process terminating in a sucking-disc; (×87).

enormous caliper-like mandibles, 0·7 mm. long, a similar but slenderer pair of maxillæ without palpi, and a small triangular labium carrying a pair of four-jointed palpi. There are no teeth on the mandibles.

The segments of the thorax are slightly narrower than the head, and subequal, the prothorax being the longer, but somewhat the narrower. The legs are short, the femora being fairly stout, the tibiæ shorter and slenderer, and the tarsi very short and unjointed. Distally, the tibiæ are armed with a pair of strong spurs. The tarsi end in a pair of short, strong claws, between which there projects a long, slender empodium, ending in an enlarged suction-disc, and closely resembling the same structure in the larva of *Chrysopidæ*. The larva is able to crawl forward slowly, but prefers to walk backwards, which it can do with considerable speed, using its anal papilla as well as its legs.

The segments of the abdomen are nine in number, together with a terminal anal papilla, which represents the reduced tenth segment and the anal appendages. These segments are narrow, and taper from before backwards. The whole of the abdomen, as well as the head and thorax, is clothed with short, stiff hairs.

The spiracles in the newly-hatched larva are eighteen in number, there being a pair upon the prothorax, and also upon each of the first eight abdominal segments. They are, however, very difficult to make out, the spiracular openings being small and devoid of armature.

When first hatched, the larva is semi-transparent, with very little colour-pattern. Later it darkens to a greyish-brown, which tends to become overlaid with a whitish pruinescence. These changes become more marked in the following instars.

At the end of the first instar, the larva has about doubled its length, and the segments of the thorax and abdomen have increased greatly in width and length, so that the head now appears very small in comparison.

As soon as the cold weather sets in, in May or June, the larva ceases to feed, and remains motionless, hiding away in a crevice of the bark, until the warmer weather begins in September. It then becomes active again; but, after one or two good meals, it again rests for some days, and then undergoes its first ecdysis. This appears to be fatal to many of the larvæ, chiefly owing to the great difficulty experienced in removing the head from the very hard shell of the cuticle enclosing it.

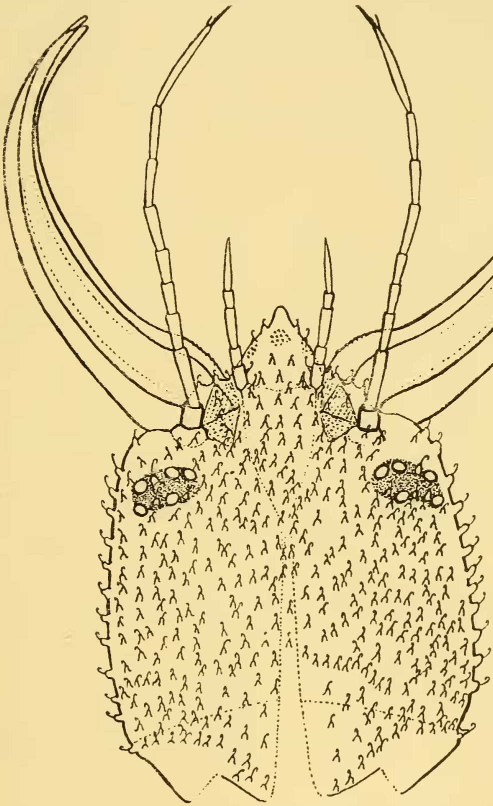
Second Larval Instar. (Plate lxxix., fig.4; Text-fig.3).

At the first ecdysis, there is a great increase in the size of the head of the larva, which now becomes about 1·4 mm. long in an average-sized larva. (There is considerable variation in the sizes of individual specimens, and this is not rectified in the imagines, which also vary greatly in size). The head becomes more definitely trapezium-shaped than before, owing to the increased definiteness of the four angles; its colour is a rich brown. An extra joint is added to the antennæ, which are now nine-jointed, and to the labial palps, which become five-jointed. The mandibles and maxillæ are almost as long as the head, shaped as in the first instar, but of stronger build. The ocelli become more plainly marked, each set of five being placed upon an irregular darkened area just behind the base of the antenna.

Text-fig.3 shows the cast skin of the head of the larva at the end of this instar. The armature of the head is very remarkable, consisting of numerous raised papillæ, from each of which a tiny hooked hair projects; these are especially conspicuous upon the sides of the head, and upon the projecting triangular labrum. The figure shows very plainly the mid-dorsal and lateral splits which take place in the cuticle at ecdysis.

As at hatching, so also at the beginning of the second instar, the three thoracic segments are approximately equal in size, the prothorax being somewhat longer and narrower than the other two. After a meal, the meso- and metathorax swell up, like the abdomen. But the prothorax can only swell up posteriorly, the neck-constriction remaining unchanged; so that this segment soon becomes much narrower than the other two. The legs remain small, and formed as in the first instar, with unjointed tarsi.

The abdomen is at first fairly slender and tapering towards the anus. As the larva feeds, it swells up rapidly, and assumes the somewhat broad, flattened shape shown in Plate lxxix., fig.4. A slight pattern becomes noticeable upon the abdomen and thorax, more markedly in some individuals than in others. This is mainly due to the onset of pruinescence, which leaves the



Text-fig.3.

Cast skin of head of larva of *Ps. elegans* (Guér.), at second ecdysis; (× 30).

original dull brownish colour of the body more definitely marked mid-dorsally and in the sutures. A pair of darkish spots can be made out on the meso- and metathorax, marking the positions of the *pinacula* of these segments (see p.800).

At the end of the second instar, the larva has increased to about 8 mm. in length, and is very stout. As this instar has been passed entirely in the summer-months, with an abundance of food and warmth, growth is comparatively rapid, and the second ecdysis usually takes place during February or March of the second year of larval life. This ecdysis does not appear to be such a crisis in the life of the larva as was the first one; possibly because the larvæ are more active in the warm weather, and make greater efforts to free themselves from the hard cuticle of the head, which is again the principal cause of any mortality that occurs at this period.

Third Larval Instar. (Plate lxxix., fig.5; Text-figs.4-9).

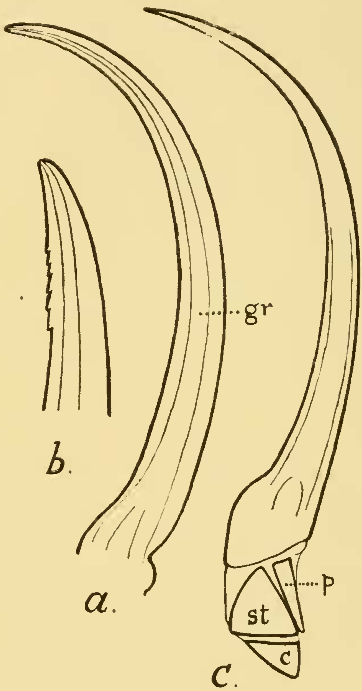
As before, this second ecdysis results in a great increase of the size of the head, which broadens considerably, becoming squarish, as shown in Plate lxxix., fig.5. The increase in length is only a moderate amount, but in breadth it is more than 50 per cent. of the width at the end of the second instar. The labrum broadens with the head, and loses its triangular shape, as may be seen by comparing Text-figs. 3 and 5. The antennæ sometimes become ten-jointed, but I have only been able to count nine in several specimens. The labial palps remain five-jointed, and there is no change in the shape of mandibles or maxillæ.

Thorax, legs, and abdomen remain of the same shape as in the second instar. The pattern varies greatly for different individuals, some being brown all over, others brown with grey pruinescence, and others entirely grey, or almost white, and strongly pruinescent all over. The head usually remains a rich dark brown; but I have seen specimens with strong pruinescence upon the head also.

During March and April of its second year of existence, the larva feeds up rapidly, and many specimens become apparently full-fed by the time winter sets in. None, however, attempt to spin up, but remain dormant in crevices of the bark until the warmer weather of the Spring returns. During this second hibernation, great mortality occurs, many larvæ being attacked by some obscure fungoid disease, and others apparently dying of cold. Out of thirty larvæ brought from Wauchope, N.S.W., in February, 1917, I succeeded in rearing only six to maturity.

Before describing the spinning of the cocoon, we may profitably study, somewhat more minutely, certain of the larval structures. as they are to be seen at the end of the third instar.

The Mandibles (Text-fig.4, *a*, *b*) are a pair of huge curved jaws, immensely strong, and of a rich dark brown colour. They are smooth in outline, and without visible teeth; but an examination under a higher power will show the presence of about six small, backwardly directed serrations on the inner edge, close up to the tip, as in Text-fig.4, *b*. These undoubtedly help in preventing the escape of the prey, when once it has been pierced by these powerful jaws. On the ventral side of each mandible, there is a very definite groove (*gr*) which receives the maxilla, lying directly below it. The length of the mandible is 2·7 mm.



Text-fig.4.*

The Maxillæ (Text-fig.4,*c*) are not unlike the mandibles in size and shape, but are slenderer, and slightly more curved towards the tip. They are entirely devoid of armature, except for their very sharp points. Each maxilla carries a very faint groove upon its dorsal surface, a little wider than the groove

* *a*, Mandible of larva of *Psychopsis elegans* (Guér.), third instar; (×30). *b*, Tip of same, to show the series of fine serrations; (×87). *c*, Maxilla of same; *c*, cardo; *p*, palpiger; *st*, stipes; (×30).

of the mandible. In the living larva, the maxillæ may be seen at times playing freely forwards and backwards beneath the mandibles; so that it is evident that they have considerable freedom of movement, in spite of being designed to act as a pair of complete sucking-tubes in conjunction with these latter.

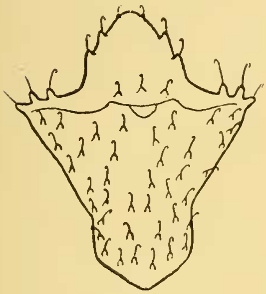
Whereas the groove in the mandible can be followed with ease right up to the tip, that of the maxilla cannot be so followed, and is evidently of a much more imperfect nature. Hence the complete sucking-tube must be formed at least partly by pressure of the two pairs of jaws, one upon the other, and not by a close interlocking of parts. I have frequently seen the tips of the maxillæ pushed a considerable distance forward beyond the tips of the mandibles; this could scarcely happen unless the fit of the maxilla upon the ventral surface of the mandible were a somewhat loose one, seeing that the calibre of the groove varies greatly from base to tip.

When the maxilla is dissected out, it is seen to be considerably swollen near the base, and to carry, below the swollen part, three flat, chitinised plates, two of which are broadly triangular, the third very narrow. These are placed in the positions of *cardo*, *stipes*, and *palpiger* of a normal maxilla, and appear to represent those three sclerites. As regards the elongated spear that forms the principal part of the maxilla, this would appear to be the galea. But, unless the transformation of these parts, from their abnormal form in the larva to their normal form in the pupa, can be followed out at metamorphosis, in such a way that there can be no doubt upon the matter, I do not think that we can be sure of their homologies.

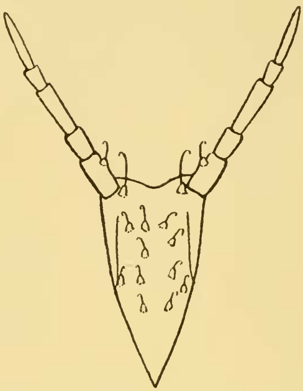
The Labrum and Clypeus (Text-fig.5). These together form one piece in the larva, indistinctly divided transversely, as shown in the figure. The clypeus is covered with the usual hooked hairs, set upon raised papillæ The labrum is a strongly projecting curved lobe, carrying only three rather large hooked hairs on either side.

The Labium (Text-fig.6). This consists of an undivided triangular basal portion, from the two anterior angles of which project the five-jointed palpi. The basal joint of each palp carries a single hooked hair on its inner side, and there is a larger one situated just below it. Five or six smaller hooked hairs are situated on either side of the middle line, upon the basal portion of the labium.

This basal portion of the labium remains undivided throughout all stages in *Psychopsis*, and probably represents both mentum and submentum combined.



Text-fig.5.*



Text-fig.6.†

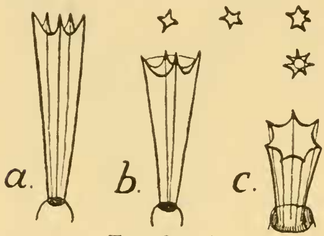
The Body-Armature (Text-figs. 7, 8). We have already described the peculiar hooked hairs, set upon raised papillæ, which are found upon the head of the larva. They also occur upon the hard tergal plate of the prothorax, which is formed of tough, dark brown chitin, like that of the head. Upon the rest of the thorax, and upon the abdomen, these hairs are almost entirely replaced by more highly specialised structures, which I shall call *dolichasters* (Greek δολιχός, long; and ἀστήρ, a star). The dolichaster is a more or less elongated, hollow, chitinous structure, set upon a definite papilla; it is very narrow at the base, but expands distad in narrow pyramidal form, and ends distally in from four to nine sharply projecting points, which pass beyond the general periphery of the enclosing chitinous membrane.

* Labrum and clypeus of larva of *Ps. elegans* (Guér.), third instar; (×30).

† Labium of larva of *Ps. elegans* (Guér.), third instar; (×30).

Viewed end on, it is more or less star-shaped, being in the form of a fairly regular polygon with concave sides. Typical dolichasters are shown in Text-fig. 7, *a*, *b*, and *c*. These structures are very abundant all over the abdomen and thorax, excepting upon the hard tergal plate of the prothorax, on which only an occasional one can be seen.

The dolichaster is clearly a specialisation from a normal hollow sensory hair or macrotrichion. This may be proved by a study of the eighth and ninth segments of the larva. On the ninth segment, the macrotrichia are of normal form. On the eighth, there are a few of normal form, but most of them are slightly thickened and blunted at the tips, and a few can be seen having the projecting distal points or angles of the true dolichaster-form. On the seventh, the dolichaster-form is fully established, but remains very elongated, for the most part. On the rest of the abdomen, all stages from a very narrow, elongated dolichaster with only four or five rays, to a shorter and stouter dolichaster with from seven to nine rays, can be easily followed.



Text-fig. 7.*

Dolichasters vary from 40 to over 100μ in length, and from about 20 to 30μ in extreme width distally.

We may compare the dolichaster with the *bulla*, such as is found in the larva of *Micropteryx* (Order Lepidoptera). In the bulla, the macrotrichial chitin becomes very soft, and the internal cavity is enlarged so that the hair expands into the form of a soft, swollen bulb. Weak longitudinal supporting rays are, however, present, as may be seen by a careful examination of the bulla under a high power. Moreover, when the bulla is viewed end on, it, too, like the dolichaster, exhibits the star-shaped

* Dolichasters from integument of larva of *Ps. elegans* (Guér.), third instar; (×330). *a*, Long, five-rayed form; *b*, four-rayed form; *c*, shorter, seven-rayed form. Above *b* and *c* are shown four examples of micrasters, also ×330.

distal end, though the periphery of the soft chitinous bulb, in this case, projects out well beyond the outline of the star. Thus the bulla is a higher specialisation from the original macrotrichion than is the dolichaster, and can be developed from the latter by further softening of the chitin forming it, and further swelling up of the internal cavity.

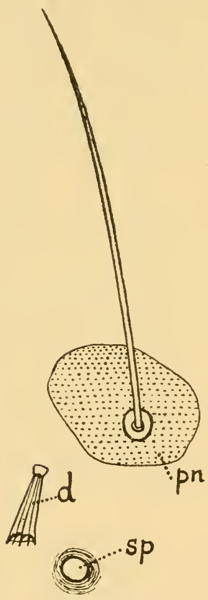
The *dolichaster* may also be compared very closely with a typical *scale*, such as is found upon the bodies of Collembola, or upon the wings of Lepidoptera. If the dolichaster were to become flattened down upon itself symmetrically from the side, it would differ very little from a scale; the longitudinal edges or rays would become the longitudinal striæ of the scale, and the sharp distal points of the dolichaster would remain as a series of distally projecting angles, such as are very commonly found in a large number of Lepidopterous scales, particularly amongst the Heteroneura.

Besides the dolichasters, the body of the larva in *Psychopsis* carries, in a number of places where the chitin is very soft, an immense number of minute, star-shaped structures, which I shall call *micrasters* (Greek μικρός, small; and ἀστήρ). Where they occur, they are developed from every single hypoderm-cell in the neighbourhood, and are thus many times more numerous than the dolichasters of the same region. The micraster is a minute, sessile, flattened star, not set upon any definite papilla, and raised but little above the general surface of the integument. Text-fig.7 shows a set of four micrasters with four, five, six, and seven rays or points respectively.

The micrasters vary from 1 to 3μ in height, and from 8 to 12μ in extreme width. Thus they are always smaller than the basal papillæ of the dolichasters, which range from 12 to over 20μ in width.

It can be easily seen that the micraster is simply a specialisation of the minute microtrichia which occur normally upon many parts of the body of an insect, especially in the sutures and other places where the chitin is soft, in the form of tiny hooked hairs. A search over the larval integument of *Psychopsis* shows that, for the most part, these microtrichia are only feebly developed, as minute processes flattened down close to the integument itself. In other places, they can be seen to be divided into two short processes at an obtuse angle to one another. From this form, the transition to a four-rayed micraster is quite a simple one. As microtrichia are developed from every single unspecialised hypoderm-cell, in the regions in which they occur, it follows that the same will be true of the micrasters in any given region, as we find to be the case here.

Pinacula, or small plates of hardened brown chitin, carrying one or more hairs or setæ, occur upon the meso- and metathorax, and also upon the sixth to eighth abdominal segments. Each segment mentioned has a single pair of pinacula placed more or less dorso-laterally.



Text-fig. 8.*

The simplest pinacula are those of the abdomen, of which one is shown in Text-fig. 8, together with its corresponding spiracle. It is a somewhat irregular oval patch, which carries a single excessively elongated and slender hair, quite unlike any other hair to be seen in this larva, and about one-third of a millimetre long. The two pinacula of the eighth segment are placed rather close together, on either side of the mid-dorsal line. Those of the seventh segment are placed further apart. Those of the sixth are much smaller, and still further apart. Sometimes a vestige of a similar pinaculum may be observed upon the fifth segment also, in good chitin-preparations.

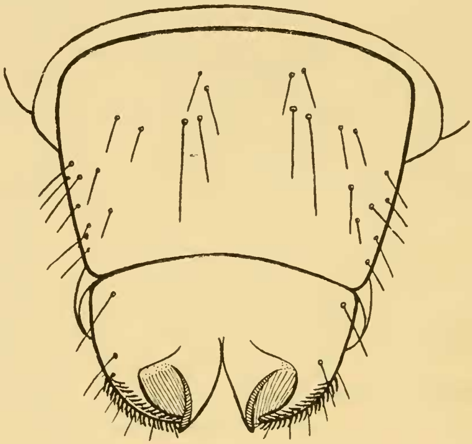
The pinacula of the meso- and metathorax are much larger and darker areas, whose position has been already indicated in

* Details from the integument of seventh abdominal segment of larva of *Ps. elegans* (Guér.), third instar. *d*, A dolichaster; *pn*, pinaculum with long, slender macrotrichion; *sp*, spiracle, in situ; (× 167). Three other dolichasters surrounding the spiracle are omitted.

describing the colour-pattern on p.793, since they occupy the darkish spots there mentioned, and shown in Plate lxxix., figs.4, 5. Each pinaculum carries from two to four dolichasters, and a single small seta upon a raised papilla. In specially good preparations, I have seen the blind ending of a small trachea upon the integument close to the pinaculum; this would appear to indicate the original position of the meso- or metathoracic spiracle, which has evidently become suppressed.

The Spiracles.—In all three larval instars, the number of functional spiracles is eighteen, viz., a pair upon the prothorax, and a pair upon each of the first eight abdominal segments. They are all very small, simple openings, the rim of which is slightly strengthened and darkened. As far as I can see, they are quite devoid of armature or ornamentation of any sort. A single trachea, whose calibre is approximately equal to that of the spiracle itself, passes inwards from it to the main tracheal trunk on each side. The prothoracic spiracles are the largest pair; next in size are those of the eighth segment, with those of the seventh, sixth, etc., in descending order of magnitude up to the first. Text-fig.8, *sp.*, shows one of the spiracles of the seventh segment *in situ*, with its corresponding pinaculum (all but one of the surrounding dolichasters removed). Owing to the great number of these latter, it is always difficult to locate the spiracles in this larva.

The Anal Papilla (Text-fig.9).—The last two segments of the abdomen, viz., the ninth and tenth, are much narrower than the rest, and are more or less retractile within the eighth. They do not carry dolichasters, but only very delicate, slender macrotrichia of reduced size. The tenth segment forms the *anal papilla* or *sucker*, by means of which the larva is enabled to move rapidly backwards, or to hold on tight when attacking its prey. This segment is furnished with a pair of dorso-lateral curved processes, probably representing the original cerci, and a pair of ventral processes, somewhat cornute in shape, and curving outwards to meet the incurving tips of the dorsal processes. These latter are armed with two series of closely set, short, sharp setæ, one set directed outwards and the other inwards. I have found it impossible to observe how these organs are used by the larva; but the result is certainly to give it a very powerful grasp upon anything that they grip, and the whole papilla appears to act as forcefully as a true sucker. Whether there is, besides the actual grasping effected by these appendages, any sucking action performed by the tenth segment, I cannot say. Remembering that the silk for the cocoon is spun from the anus, it seems possible that an exudation of the same nature may help in the action of the anal papilla as a grasping or sucking organ.



Text-fig. 9.
Anal papilla of larva of *Ps. elegans* (Guér.), third instar; ventral view; (×87).

Habits of the Larva.

In order to discover the larva in its natural haunts, it is necessary to provide oneself with a stout, wide-bladed chisel, or some other instrument that will act as a lever for removing the bark of Myrtaceous trees. The ordinary methods of bark-collecting, as practised by Coleopterists, are useless in this case. All old trees, in which the bark is hanging in shreds or long strips, or is dry and attacked by white ants, are of no use in searching for *Psychopsis* larvæ. Instead, it is necessary to select healthy, medium-sized trees, in which the sap is running freely, and in which, consequently, the bark, when torn away, is found to be slightly moist inside. The best trees are those in which the bark is thick and rough, with many crevices, as in the case of the Ironbark (*Eucalyptus siderophloia* Benth.) and Bloodwood (*E. corymbosa* Sm.). Probably the Ironbark is one of the best trees of all for this larva; but it is so difficult to work, on account of the extreme toughness of its bark, that it is best to leave it alone, unless one sees a piece of bark that can be levered off without damage to one's tools. Around Sydney, one of the very best trees is the Bloodwood; but in Queensland, where the bark of this tree is thinner and more scaly, I met with little success in exploring it. Another excellent tree is the Forest Apple (*Angophora intermedia* DC.). Trees in which the bark comes away in long strips of considerable thickness, such as the Tallow-wood (*E. microcorys* F.v.M.), Turpentine (*Syncarpia laurifolia* Ten.), and Stringy-bark (*E. capitellata* Sm.), generally provide very good hunting also; but those with thin bark are useless.

In searching for the larva, of which, probably, not more than five or six at the most would be found on any given tree, even if all the bark were to be stripped from it, much time and trouble may be saved if one watches for likely places where the larva may be expected to hide. Such are, for instance, particularly thick or richly creviced portions of bark; and, above all, the cracks and crannies surrounding a gum-flow. Many insects come at night to taste this gum; and it is to be presumed that the *Psychopsis* larva takes up his station near by, with the special object of attacking these insects. On One Tree Hill, Brisbane, I noticed a rather small Ironbark-tree, in which there was a good gum-flow, caused by a small cut with an axe. By levering up the two tough projecting ends of the bark, above and below this cut, I secured four larvæ of *Ps. elegans* and two of *Ps. cœlivagus*—the best haul I ever obtained from a single tree.

When a piece of bark is removed, the *Psychopsis* larva will almost always be found upon the trunk of the tree, with its body flattened down, and quite motionless. Thus, the trunk and its exposed crevices should be examined first; then, if nothing is seen there, the piece of bark may be likewise examined, and sometimes yields a larva. Very soon the larva will begin to move rapidly backwards, feeling all the time, with its mobile anal papilla, for a suitable crevice in which to hide. If once it succeeds in reaching one, it will not be easy to secure it. Hence it should be picked up at once with the forceps, and transferred to a glass-tube, whose open end should be stopped up with cotton-wool. Not more than one larva must be put into one tube, unless each is separated from the next by a plug of cotton-wool; for one is sure to attack the other and suck him dry.

The larva may be reared right through, in a single small glass-tube. The best food for the earlier stages is white-ants. These should be given alive, but with their heads crushed; otherwise there will be a fight between the larva and its intended victim, in which the tables may be turned. In the second and third instars, the larvæ of the Codlin Moth make excellent food; but these also must be offered with their heads crushed, unless one is willing to take the risk of damage to the *Psychopsis* larva from the strong mandibles of the Codlin grub. Under natural conditions, the *Psychopsis* larva guards himself from attacks of this kind by retreating into a crevice, after he has seized his prey. With his body thus covered, and only his large jaws projecting, he is perfectly safe. But it is different in a glass-tube, where the whole of the larva's soft body is exposed to attack from the jaws of his writhing victim.

The larvæ feed but seldom; each meal, however, is a very substantial one. A larva supplied with a Codlin grub will usually attack it at once, advancing cautiously with its jaws wide apart, until they are well placed on each side of its victim. Then, with a sudden vicious snap, the jaws are driven home, and the victim is secured. If the victim struggles furiously, the *Psychopsis* larva will frequently let go its hold, and retreat into a corner, with every sign of fear; nor will it be induced to attack the same victim a second time. Generally, however, the larva is able to hold on, until the loss of blood occasioned by the wound weakens the victim sufficiently to prevent its struggling further. Then the jaws are driven far in, and the play of the maxillæ to and fro beneath the grooved mandibles shows that the larva is sucking vigorously at its victim. It may take some hours before the latter is completely emptied of its juices. By this time, the *Psychopsis* larva will have swollen out to a very great extent, and will frequently be quite torpid, like a snake. After such a meal, no food should again be offered for two or three weeks. Larvæ that are overfed usually die from the effects of it; so that it is necessary to keep a strict watch on the feeding, and only to offer food to those that are really in need of it.

The Cocoon. (Plate lxxix., fig.6).

When the larva is full-fed, it remains torpid for a considerable period, usually two or three weeks. It then sets about constructing its cocoon. First of all, a number of loose and irregular threads are spun from the anus, making an irregular meshwork, the size and appearance of which depends entirely upon the place selected for the cocoon. Under natural conditions, the cocoon is spun in a crevice of the bark, which is usually barely wide enough to contain it. In such a case, the preliminary meshwork is reduced to a minimum, and only consists of a slight scaffolding or anchorage for the cocoon. But, in such an artificial condition as in a glass-tube, the larva may expend a considerable amount of skill upon this meshwork, before it is satisfied that conditions are satisfactory for the actual building of the cocoon.

Having selected the exact position for the cocoon, the larva next spins a small platform within the meshwork already mentioned. Upon this it lies, back downwards, while it weaves around itself, with marvellous dexterity, the beautiful spherical cocoon. The outer sheath of the cocoon is mostly composed of fairly loose and irregular threads; as these are spun in larger and larger number, the spherical shape of the cocoon begins to take shape. Within this loose outer covering, the threads are spun with wonderful accuracy and closeness, so that the larva is finally enclosed in a dense white or cream-coloured ball of silk, which, when cleared of its outer and looser threads, closely resembles a pearl. As the spinning proceeds, the larva shrinks more and more in size, and becomes doubled right over upon itself. When the cocoon is finished, it becomes almost impossible to conceive how so large a larva could have managed to encase itself in it.

As regards the actual mode of spinning the thread, the mobility of the anal papilla is very marvellous. Lying upon its back, the larva can protrude this papilla to a great distance, and spin silk all round itself, even behind its head and thorax, with very little effort. Most of the threads, however, are spun transversely across the larva, beginning with a small arc at the anal end, then swinging out into a longer arc across the middle of the abdomen, and finally making shorter arcs behind the back of the thorax. All these transverse strands appear to be carefully connected, on both sides, with the small platform already mentioned, which itself is made to form a part of the outermost coat of the cocoon. When the first complete layer of the sphere is finished, the larva has its head bent over so as almost to touch the tip of its abdomen; but the mobility of the anal papilla appears to be but little decreased in this position. In spinning the inner layers of the cocoon, the larva changes its position every now and then, so that the anal papilla may cover all parts of the sphere with an equally thick layer of silk.

As found under natural conditions, the cocoon is an oblate spheroid, with the two poles in contact with the sides of the crevice in which it is placed, and the larva lying so that its sagittal section is in the equatorial plane of the spheroid. When spun, however, in an open tube, the cocoon is practically a sphere. It closely resembles the cocoon of a Chrysopid, particularly that of the genus *Nothochrysa*, from which it would not be possible to distinguish it for certain. But, unlike most of the *Chrysopidæ*, *Psychopsis* does not attempt to spin any external matter into the outer mesh of the cocoon. Such a proceeding is, of course, unnecessary, considering the position in which it is placed. The diameter of the cocoon varies with the size of the larva, but is usually about 5 mm. (Plate lxxix., fig.6).

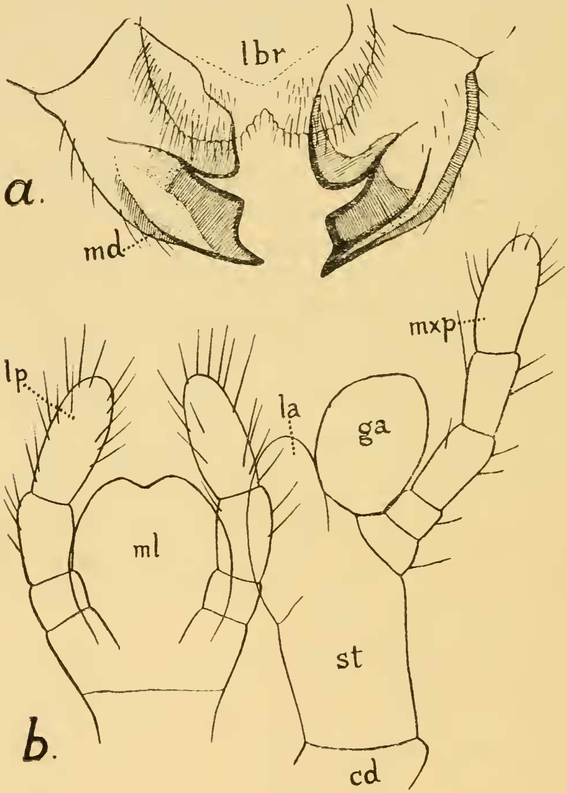
The Pupa. (Plate lxxix., fig.7; Text-fig.10).

As far as the external form is concerned, the true metamorphosis is that between larva and pupa. The latter is a *pupa* *libera*, closely resembling the imago in everything except its unexpanded wings (Plate lxxix., fig.7). At the metamorphosis, the pupa experiences a great difficulty in casting off the hard larval head, and a number perish from inability to do so. The rest of the larval skin is soft, and shrivels up into a minute mass within the cocoon; the head may be found sometimes almost intact, sometimes with the mandibles and maxillæ broken off from it. The splitting of the head is mid-dorsally and postero-transversely, as in the other larval ecdyses (Text-fig.3).

The change from larva to pupa does not take place until a considerable time after the spinning of the cocoon, generally from a fortnight to three weeks. At first, the fresh pupa is almost colourless, the body having a slight greenish tinge, the head and wings cream-coloured. The compound eyes are large, and soon become dark brown and functional. If the cocoon be opened, the pupa watches every movement with anxiety, and can be made to turn round and round, merely by the movement of a pin held at a short distance in front of the head.

The *antennæ* are fairly short (Plate lxxix., fig.7), but are composed of a large number of joints, there being thirty-five in the pupa which I dissected. Each joint is less than half as long as wide, except only the first three; of these, the basal joint is stouter than the rest. Unlike those of the imago, the antennæ in the pupa are devoid of hairs.

The mouth-parts are of considerable interest (Text-fig.10). The *labrum* is distinctly bifid, and carries numerous hairs on small raised bases. Below the labrum, on either side, are the large and very strongly chitinised *mandibles*. Each of these consists definitely of two lobes, separated by a narrow slit. The outer or distal lobe has a sharply pointed, tooth-like apex, and, below it, a more or less broad and flat cutting-area, forming a right-angled projection. The inner or basal lobe is rounded, and much less prominent. The two mandibles are not similar in shape. The right mandible has the smaller basal lobe, but the broader and flatter cutting-surface; whereas the left mandible has the cutting-area narrower, and the apical tooth raised above it on a high ridge. Thus, in the action of cutting open the cocoon, for which these strong mandibles are employed, it is evident that the apex of the right mandible plays in and out of the groove formed between the apical ridge of the left mandible and the



Text-fig. 10.

Mouth-parts of pupa of *Ps. elegans* (Guér.). *a*, Labrum (*lbr*) and mandibles (*md*). *b*, Right maxilla and labium; *cd* cardo, *ga* galea, *la* lacinia, *lp* labial palp, *ml* median lobe of labium, *mxp* maxillary palp, *st* stipes; (×48).

rectangular shelf below it. This is also proved by the fact that the cutting-edge of the distal lobe of the right mandible is very sharp, whereas that of the left mandible is thicker and blunter, and is evidently formed more as a pad or receptacle, against which the right mandible can work.

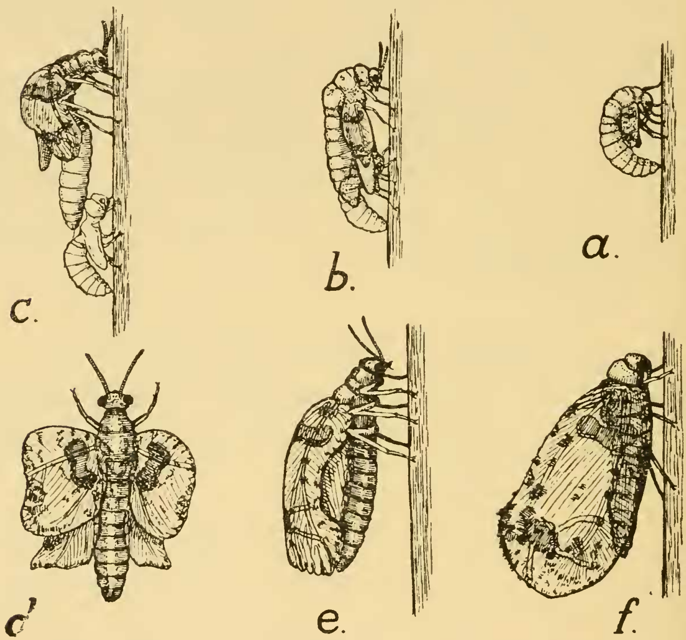
The *maxillæ* and *labium* resemble those of the imago fairly closely, but are broader and softer, as if the parts were all swathed in whitish bandages. The principal differences are that the galea of the maxilla is a broad rounded lobe without a small distal joint, and the median lobe of the labium is simply bifid, instead of being formed as in the imago.

After about a week, the imaginal colours begin to appear upon the body and wings of the pupa. Before emergence, the whole beautiful pattern of the wing-colouration becomes set forth upon the wings of the pupa. It was by this means that I was able to recognise the pupa of *Ps. cœlivagus*, with its intensely black wings, in spite of the fact that it failed to complete its emergence, after escaping from its cocoon.

Emergence of the Imago. (Text-fig.11).

The pupa emerges from the cocoon by cutting it neatly open with its sharp mandibles, whose scissor-like action is specially adapted to this purpose. About one-fourth of the circumference is left uncut, forming a strong hinge. The pupa pushes up the lid of the cocoon, and climbs out.

On Dec. 1st, 1915, at 5.30 p.m., I noticed a pupa emerging from its cocoon, which was placed upon some sand in a glass-jar. The pupa crawled along the sand to a strip of blotting-paper, placed nearly vertically, near by. Up this it climbed to a height of about one and a half inches, and then took a firm grip of the blotting-paper with its claws, and remained resting for a few minutes. During this time, it gradually swelled up and became very taut, as shown in Text-fig.11, *a*. At 5.37 p.m., it began to work its abdomen and wing-sheaths about; so that, in a few seconds, the fine pupal skin split dorsally down the thorax, the abdomen became straightened out, and the imago began to emerge from the pupal skin. During emergence, the wings begin to expand at once, the insect arching them strongly outwards, as may be seen in Text-fig.11, *c*, *d*. The basal portions of the wings begin to enlarge before the apical portions are freed from the pupal wing-sheaths. Consequently, as in the case of the Stone-flies or Perlaria, the wings, when finally withdrawn, have the distal portion bent at an angle to the basal portion, as shown in Text-fig.11, *d*. This applies more to the forewing than to the hind, which becomes freed with less difficulty.



Text-fig.11.

Emergence of the imago of *Ps. elegans* (Guér.). *a*, Pupa just before metamorphosis, 5.36 p.m. *b*, Imago emerging, 5.40 p.m. *c*, Imago freed from pupal skin, 5 42 p.m. *d*, Imago expanding its wings, 5.47 p.m. *e*, The same at 5.49 p.m. *f*, Imago resting with wings fully expanded, 6.8 p.m. (Drawn from sketches made while watching the actual emergence on Dec. 1st, 1915; *d*, dorsal view, the rest lateral).

As soon as the imago was quite free, it climbed upwards further away from the pupal skin, the latter being left clinging to the blotting-paper, as shown in Text-fig.11, *c*. Having taken up a position well above the pupal skin, the imago remained stationary with its wings arched strongly outwards, the forewing at first completely hiding the hindwing. While the basal half of the forewing expanded rapidly, the distal half remained bent under it for some time. Meanwhile, the hindwings expanded rapidly, and their apical portions appeared beneath the still bent forewings, as seen in Text-fig.11, *d*. Next, the distal portions of the forewings became straightened out, though at first they remained full of longitudinal rucks, as seen in Text-fig.11, *e*. The wings were held well away from the abdomen up to 5.49 p.m., by which time they were about three-fourths expanded. Then the apical rucks became rapidly smoothed out, and the wings were arched forwards, forming a steep roof over the body, so that the costal margins of the forewings come almost into contact with the blotting-paper (Text-fig.11, *f*). From the time of leaving the cocoon to the time that the wings were fully expanded, only thirty-eight minutes elapsed. After resting for some time in the position shown in Text-fig.11, *f*, until its wings were sufficiently hardened, the imago spread them out in the broad, flattened, roof-like manner usually adopted in this family.

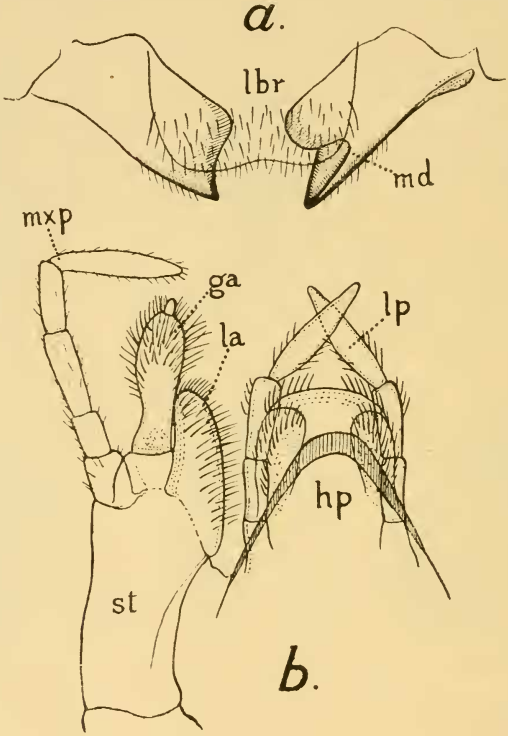
The pupal skin left behind is a flimsy, white structure. It is very difficult to detach from its position. But, when once this has been done, the slightest breath of air causes it to move readily, so light and delicate is its construction. The thorax and base of the abdomen are flattened, and wide open dorsally. From the prothoracic spiracles, two long threads stand up; these are the intima of the tracheal trunks, withdrawn through these spiracles when the imago emerges. The back of the head is split open, and the large dark brown pupal mandibles are left gaping wide apart.

The Imago. (Text-fig.12).

A few details about the imago which have not been published may suitably be given here.

The mouth-parts are figured in Text-fig.12. The *labrum* resembles that of the pupa, but is not definitely bifid, there being only a very slight indication of the division into two distinct lobes. It carries numerous hairs, not set upon raised bases.

The *mandibles* are smaller and weaker than in the pupa, and show considerable modification in shape. The right mandible in the imago has only a single lobe, with a less prominent apical tooth and a broader cutting-blade. The left mandible, on the other hand, is still bilobed, the basal lobe being rounded as in the pupa, but the distal lobe forming a single strongly projecting



Text-fig. 12.

Mouth-parts of imago of *Ps. elegans* (Guér.), ♀. *a*, Labrum and mandibles. *b*, Left maxilla and labium; *hp* hypopharynx; rest of lettering as in Text-fig. 10; (×48).

tooth, whose internal border is definitely hollowed out. Thus, in the imago, the cutting-edge of the right mandible works into the groove of the left in a very simple manner. These mandibles may possibly be used for feeding upon gum-exudations. In captivity, the insects feed willingly upon sugar moistened with water and spread upon cotton-wool, using their mandibles to chew the sticky crystals.

The *maxillæ* are of a very generalised type, with complete and separate galea and lacinia, and an elongated, five-jointed palp. The stipes is long, the cardo very short. The lacinia arises from a broad oblique base, in the form of a simple elongated lobe with rounded apex, and carrying numerous hairs. The galea is remarkable in being set well above the lacinia, upon a short transverse base formed as a definite projection from the stipes, and also in carrying a small but very definite distal joint. The basal joint is somewhat club-shaped, and carries numerous hairs upon its distal half. It is possible that the existence of a distal joint is an archaic feature, and that it may prove to be of importance in the study of the Phylogeny of the Holometabola.

The maxillary palp is carried, in the position of rest, with its distal joint turned inwards almost at right-angles to the other four, as shown in Text-fig.12, *b*. The first and second joints are short, the third twice as long as the second, the fourth shorter than the third, and the distal joint longer than any, with a somewhat pointed tip.

The *labium* is in the form of a broadly rounded median lobe, on each side of which there is a narrower lobe, also rounded, but folded over above the median lobe, between it and the hypopharynx. The median lobe carries hairs on either side, distally; the two lateral lobes carry numerous hairs upon their upper surfaces. The palps, which arise low down towards the base of the median lobe, are three-jointed, the basal joint being the shortest, and the distal the longest; each joint carries a few hairs.

In the natural position, if the mouth be opened, there will be seen a broad sub-triangular lobe projecting outwards and slightly upwards above the labium. This is the *hypopharynx* (Text-fig. 12, *hp*). Its distal border is well rounded, rather strongly chitinised, and curved over; it carries no hairs.

Bearing in mind the fact that the *Psychopsidæ* are the most ancient of existing Planipennia, as far as the Palæontological record of this Order is known, it would seem that much valuable evidence should be obtainable when a careful comparison can be made between the mouth-parts here described and those found in other families of the Order. This research, I hope to carry out later on.

Habits of the Imago.

During the day-time, the imagines rest concealed and motionless, either upon the underside of a leaf, or hidden away in *débris* of dead leaves and sticks. Hence they are seldom captured, though occasionally one may be taken by beating.

At night-time, they become comparatively lively. *Ps. elegans*, kept in a large glass-jar, was watched by me for several nights from 8 to 10 p.m. During this time, it fluttered about the jar, visited the moist sugar supplied as food for it, and fed upon it for periods up to half-an-hour in duration. The third night, after all the insects had fed, I was fortunate enough to see the process of pairing. The female took up a position upon a strip of bark, resting with her wings in the usual position, but continually vibrating them. A male, after several short flights, at last alighted upon the same piece of bark, lower down, and began to climb up towards the female, also vibrating his wings. At last he arrived alongside her, on her right side. The female then raised her right pair of wings, and the male moved in towards her from the side, so that the abdomens of the two insects were almost parallel, and the right pair of wings of the female covered the left side of the male. In this position they remained for pairing, occasionally vibrating their wings. It was not easy to make out exactly how copulation was effected; but it appeared that the male bent the tip of his abdomen round towards the female, and seized her with his anal appendages, at the same time pulling the tip of her abdomen partly round towards him. Thus they remained for some twenty minutes, until a second male came and alighted close to them, and began to flutter around and over them.

The female apparently did not lay any eggs until some time after pairing, as I searched the jar the following morning and found none. However, during the next few days, she deposited eggs singly, and at long intervals of time apart, in the cotton-wool which I had supplied for that purpose. She also explored the bark, but found it for the most part unsuitable, laying only one egg there, as against eleven laid on the cotton-wool. The two eggs shown in Text-fig.1 were laid close together as drawn, but all the rest were quite separate. This female may, of course, have laid other eggs which I failed to find. I should say that a single female must contain at least fifty eggs;* but it is possible that they would not usually all be laid after a single pairing.

The males were kept alive for periods varying from ten days to three weeks. The females live longer, and one was kept alive for over a month, by which time her wings were considerably torn. The only nourishment given, during all this time, was sugar and water, which I find sufficient for most Planipennia and Mecoptera. A very slight degree of moisture is required in the jar. Either excess of moisture, or exposure to a hot drying wind, is equally injurious to these insects. The same may be said of all Planipennia, although the *Myrmeleontidæ* and *Ascalaphidæ* can stand greater heat and desiccation than any of the others.

The Economic Value of the Psychopsidæ.

There is no Order of Insects, with the exception of the Hymenoptera, whose members are so generally beneficial to mankind as the Planipennia. It seems, therefore, of considerable importance that we should now attempt to estimate the value of the *Psychopsidæ* in this respect.

From the account of the life-history here given, it will be seen at once that these insects are entirely beneficial to man throughout their whole life. The preference shown by the larva for feeding upon such obnoxious insects as the larvæ of Codlin Moth, and other of the smaller Lepidoptera, at once establishes it as *potentially* a very useful factor in the checking of insect-pests. Hence, if colonies of *Psychopsis* could be established in our apple-, pear-, and quince-orchards, there is no doubt that they would help very materially in checking the Codlin Moth and other Lepidopterous pests that still do so much damage therein.

* Mr. Gallard's original female laid over fifty eggs. See p.787.

In attempting to estimate the practicability of such a suggestion, we have to bear in mind certain factors that must, at the best, very much limit the efficacy of the *Psychopsidæ*:—

(1) Although a single larva of *Ps. elegans*, during its life, would most certainly consume a considerable number of Codlin Moth larvæ, yet the value of this is much discounted by the long life of the larva, which takes up the best part of two years. The economic value of this insect would be many times enhanced if it were able to pass through all three larval stages in a few weeks, as is the case with the *Chrysopidæ* and *Hemerobiidæ*.

(2) The larva requires rough-barked trees to live in. Thus it would seem that it could only be successfully introduced into orchards in which the trees were of considerable age. Such trees would probably afford the requisite amount of shelter to the larva, which would certainly take heavy toll of any other insects that attempted to hide away in the crannies and crevices of the bark.

(3) As an archaic survival of a very old stock, the *Psychopsidæ* could scarcely be expected to show that readiness to adapt themselves to new conditions, that is to be found, for instance, in the more specialised *Chrysopidæ* and *Hemerobiidæ*. Many of our Australian species of these two families have readily established themselves in our orchards and gardens, without any attempt on the part of entomologists to place them there; and are already acting very effectively as checks upon Aphidæ and Scale Insects. So far, no similar tendency has been noted in the *Psychopsidæ*; unless, indeed, the apparent increase in the numbers of *Ps. insolens* in such districts as Killarney and Mount Tambourine, in South Queensland, where orchards are rapidly replacing the original bush, is an indication that this species is beginning to accommodate itself to new conditions. It would be natural to suppose that insects which, in a state of nature, are so rare as the *Psychopsidæ*, would not take kindly to a change of environment which man might attempt to force upon them. Thus, if a selected orchard of old trees were to be well stocked with *Psychopsis*-larvæ, one would anticipate that the resulting imagines, after pairing, would return to the nearest piece of untouched

bush, and lay their eggs, as usual, on the bark of Myrtaceous trees.

(4) The apparent association of the *Psychopsidæ* with trees belonging to the Natural Order Myrtaceæ must be considered as a disadvantage, if it is actually a fact. But, so far, we do not know the life-histories of most of the *Psychopsidæ*; and it may well be that this supposed limitation does not hold for most of the species. Moreover, it is noteworthy that, although *Ps. insolens* is our commonest species, no larva of this insect has yet been found under Eucalyptus-bark. If the life-history of this species can be worked out, it seems probable that it might prove to be of considerable value as a beneficial insect in checking orchard-pests.*

(5) The small number of eggs laid by the females is a distinct disadvantage economically. Against this, however, we may place the fact that the females live a long time, and deposit their eggs singly in many different places, instead of all in a lump. Thus the maximum effect is produced for the small number of larvæ hatched, and the danger of a quick reduction through cannibalism is eliminated.

Taking all these factors into consideration, I have come to the conclusion that, although the *Psychopidæ* do not offer us the promise of such immediately beneficial results as could be obtained by a scientific breeding and distribution of *Chrysopidæ* or *Hemerobiidæ*, yet they are a group that most certainly ought not to be neglected by economic entomologists. A few carefully devised experiments upon old and badly infected orchards, either with the larvæ of *Ps. elegans*, or with those of *Ps. insolens*, if they can be obtained by pairing the imagines, should be well worth carrying out, and might conceivably yield results much superior to the expectations that I have here indicated. There is also the possibility that these insects, like so many other Australian animals, would do exceptionally well in some new region,

* *Psychopsidæ* occur also in Africa and Asia, but nothing is known of their life-histories in these regions. Large, rough-barked Myrtaceous trees, like the Eucalypts, being absent from these regions, it is evident that they must be associated with trees of other Orders.

such as California or South Africa. As they are entirely beneficial, I would call the attention of entomologists to their possible value in this respect; particularly as there would not be the slightest difficulty in sending the larvæ to any part of the world, since they are very hardy, and will go without food for several weeks at a time.

EXPLANATION OF PLATE LXXIX.

Psychopsis elegans (Guér.).

Fig.1.—Two eggs; (×7).

Fig.2.—Newly hatched larva; (×7).

Fig.3.—The same larva at end of first instar; (×7).

Fig.4.—The same larva, at end of second instar; (×7).

Fig.5.—The same larva, at end of third instar; full-fed; (×7).

Fig.6.—Cocoon; (×4).

Fig.7.—Pupa, ten days old, extracted from cocoon; (×7).